SHIP PRODUCTION COMMITTEE
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EDUCATION AND TRAINING

September 1992
NSRP 0383

THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

1992 Ship Production Symposium Proceedings

Paper No. 6B-2: Considerations for Earlier Design for Production

U.S. DEPARTMENT OF THE NAVY
CARDEROCK DIVISION,
NAVAL SURFACE WARFARE CENTER

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **SEP 1992**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **The National Shipbuilding Research Program, 1992 Ship Production Symposium Proceedings, Paper No. 6B-2: Considerations for Earlier Design for Production**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Surface Warfare Center CD Code 2230-Design Integration Tools Bldg 192, Room 128 9500 MacArthur Blvd, Bethesda, MD 20817-5000**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**17**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

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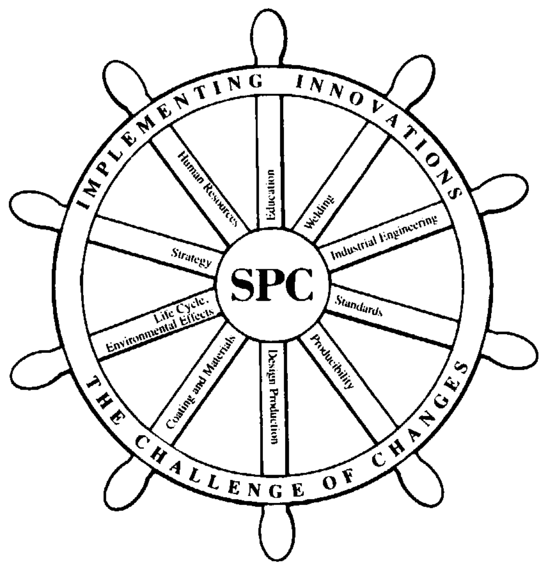
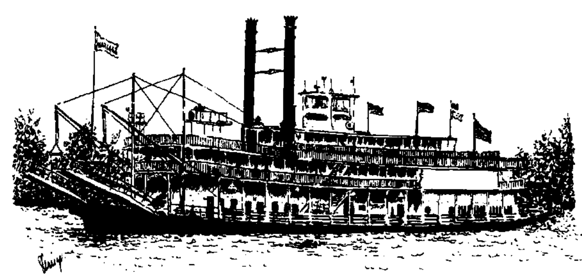


SEPTEMBER 2 - 4, 1992
New Orleans Hyatt Regency
NEW ORLEANS, LOUISIANA



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Paper presented at the NSRP 1992 Ship Production Symposium New Orleans Hyatt Regency. New Orleans. Louisiana. September 2-4. 1992

Considerations For Earlier Design For Production

No. 6B-2

John C. Daidola, Member

ABSTRACT

The principal theme of this presentation is advancing the transition of the system design orientation to planning unit orientation to a point earlier in the design phases. Achieving earlier design for production should favorably impact ship cost estimating and therefore bidding, detail design and construction schedule and cost. Recent papers on design for production have principally been concerned with those technical characteristics of the ship that are conducive to the facilitation of production. This paper emphasizes the ship construction method and sequence and how this can be introduced at a stage earlier than the Transition Design. Primary concerns are to develop preliminary build strategy, subdividing of the hull into erection units and modules, and advance planning for the development of work instruction packages during the detail design.

INTRODUCTION

It has been noted that about 30% of the difference in productivity between the typical U.S. yard and good foreign yards can be accounted for by superior design for production in the foreign yards (1). Accordingly any improvement in this stage of ship construction can have a major impact on the cost of ships.

The traditional role of the ship designer has firstly been the preparation of an overall vcsscl design which has performance characteristics satisfying the operational or functional requirements. The concept of design for production, however, requires that in satisfying these requirements, the ship designer must also give attention to facilitation of production. The need for personnel at the design stage to understand production requirements and for production departments to understand design procedures and requirements is greater than ever.

The design stage and process in shipbuilding consists of a sequential series of design phases: Conceptual, Preliminary, Contract, Functional, Transition and Detail. Transition Design is the point at which there is a translation of the design from a systems orientation, necessary to establish functional performance, to a planning unit orientation necessary to establish production requirements. These phases and the product-oriented design process are shown in Figure 1 where the term Basic Design can be taken as the culmination of the Conceptual, Preliminary and Contract Designs.

As the Contract Design is aimed at providing a basis of a contractual arrangement, if the transition to production orientation is emphasized at this point it will both aid in arriving at a less expensive design effort during construction and provide information for cost estimators to more meaningfully introduce the impact of productivity into the quoted price. It will also shorten or eliminate the precious and costly time at the outset of a construction program to establish the Transition Design.

In other cases, the Conceptual/ Preliminary Design may represent the stage at which rough order of magnitude (ROM) price quotations may be required for a timely response to a potential buyer. Failing to incorporate the impact of production enhancements on cost

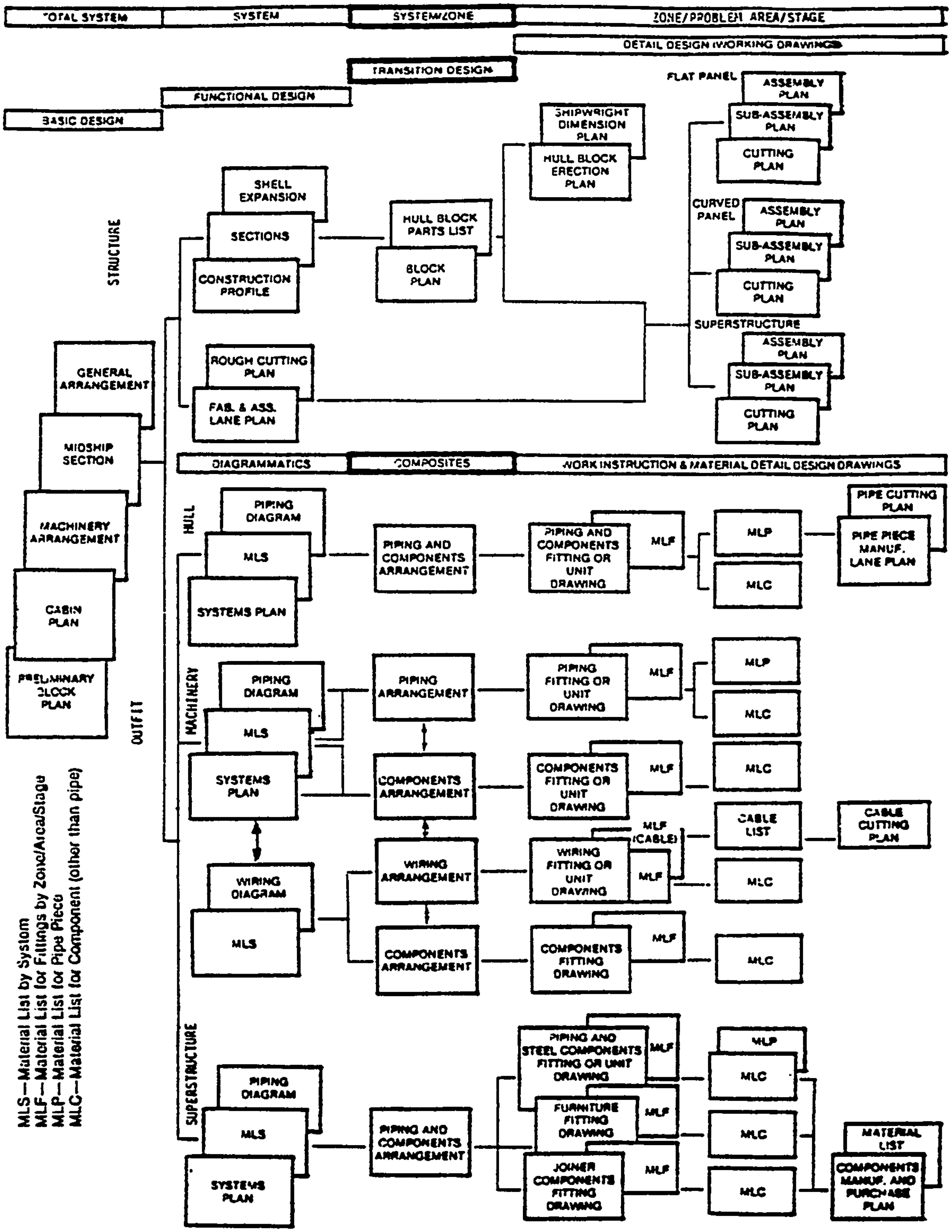

Figure 1: Product-Oriented Design Process (2)

may result in missing the competitive range and the opportunity to enter into a Contract Design.

As a result, this paper suggests emphasizing the ship construction method and sequence during design and considers how this may be introduced at a phase earlier than the Transition Design. Recent papers on design for production have principally been concerned with those technical characteristics of the ship that are conducive to the facililation of production. Both of these matters are very important to ship production but they arc distinct.

The paper first reviews the design phases and the design and production inputs and outputs which are possible. The impact of the source requesting the design on the philosophy behind it is considered from the perspective of a commercial owner, government and private shipyard. The benefit to each in incorporating earlier design for production is addressed as well. The means of incorporating design for production through a Production Directorate are then considered. Conclusions and recommendations arc offered.

DESIGN PHASES

In discussing any aspect of ship design and construction, it is essential to have a basis for definition of the levels of design consistent with stages of development of the ship. As these vary from one case to another, those which have been adopted herein arc consistent with those previously defined by the National Shipbuilding Research Program (NSRP)(1) supplemented with design related definitions (3).

Conceptual/Preliminary Design

The conceptual design phase establishes an overall design to meet an owner's outline specification. It can also define a marketable design as part of a shipyard's product development. Essentially, it embodies technical feasibility studies to determine such fundamental elements of the proposed ship as length, beam, depth, draft, fullness, power or alternative sets of characteristics, all of which meet the required speed, range, cargo cubic, payload or deadweight. Although the main outcome is a design to meet specified ship mission requirements, an account can and should be taken of production requirements. At this stage the designer has considerable flexibility in his choice of dimensions and other parameters which define the vessel and those selected can be for enhanced production.

The preliminary design builds on the concept design with the intent of solidifying certain vessel principal characteristics. These usually include the vessel length, beam, propulsion power, and displacement. Its completion provides a precise definition of a vessel that will meet the mission requirements. Concurrently with the fixing of certain vessel principal characteristics it is possible to further elaborate on the production scenario.

The content of any design phase can be defined as a series of inputs and outputs. For the concept/ preliminary design inputs may be presented in the form of an outline specification or mission requirements. A more complete summary of inputs and output items is as follows:

Design Input
- Service requirements,
- Routes,
- Market forecasts, and
- Critical components and equipment: and

Design Outputs
- Preliminary general arrangement, midship section,
- Preliminary specification,
- Preliminary calculations (dimensions. capacities, etc.), and
- Preliminary hull form body plan and lines.

Simultaneously, at this stage the shipbuilder or production discipline should identify the following essential production inputs and outputs:

Production Inputs

- Shipbuilding policy,
- Type plan,
- Facility dimension and capacities.
- Interim product types, including units and modules, and
- Material and fabrication, choices; and

Production Outputs

- Outline build strategy.
- Preliminary block breakdown.
- Zone identification,
- Material preferences; and,
- Fabrication preferences.

Preliminary Arrangements. The general arrangcmcnt is among the most important aspects of preliminary ship design as it largely dclincs the operational efficiency and functional effectiveness of a vessel. The arrangement drawings must consider the functional spaces, cargo spaces, superstructure, machinery spaces and their relationships. No less important is the provision for access between all spaces meeting operational and regulatory requirements.

The machinery arrangements during this phase may be incorporated in the general arrangement. The principal features are the main propulsion and auxiliary machinery including the main engine and large auxiliaries, electrical generators, switchboards and control areas, shafting, propellers, and the steering gear. The main engine and shafting may be the only machinery actually shown with space allocation provided for the remaining.

The general and machinery arrangements of the nature described provide a blueprint of space allocation which can be utilized for determination of preliminary block breakdown, unit definition and module considerations. It is at this point where major changes to the design to best accommodate these production considerations can be introduced and the arrangements of the vessel altered to suit.

Hull Form. During the conceptual design phase the designer is guided by an outline specification produced by the owner or on information direct from market analysis. In developing the main dimensions, account must be taken of service restrictions, for example, canal restrictions on beam or port restrictions on draft. At the same time, the capacity of various production facilities to build the design can be a consideration in terms of allowable principal hull form dimensions and the impact of length and lightship draft on launching and Fitting out.

The preliminary design process starts with the development of the preliminary body plan and lines. The location and spacing of main transverse watertight bulkheads should be established and calculations concerning flooding and preliminary damage stability conducted. Positioning the bulkheads will be dependent on cargo or other space requirements, and on flooding and stability requirements. At the same time, given the availability of a type plan, the bulkheads can be positioned to address production needs.

The hull form should have characteristics conducive lo producibility which can include parallel midbody, minimization of curvature, straight sheer and camber. Those attributes which are best suited to the shipyard and within the technical, functional and intended service considerations should be adopted.

Preliminary Calculations. At the outset of the Preliminary Design Phase, an estimation of the power required to drive the vessel at the desired speed is obtained and power calculations should continue with the interjection of hull form adjustments.

Estimates of vessel weight must be maintained during all phases in the development of the design. The designer should be aware of the placement of major machinery components and their effect on the balance of the vessel. Weight estimates are needed to establish stability, trim and list of the vessel, in addition to ascertaining the design deadweight. The basic weight calculations form the basis for estimating the cost of the vessel.

Although weight is an appropriate parameter for an initial cost estimate. it must be treated with caution. A reduction in weight will reduce the relevant material cost, but will not necessarily reduce the production cost. In some circumstances it may result in a cost increase as more costly fabrication or equipment may be involved. With the potential improvement in production with a comprehensive build strategy introduced early on. weight can only give a partial indication of cost. Labor costs as affected by producibility should impact more critically than relative changes in weight.

Structural Drawings. Upon completion of the preliminary general arrangement a midship section is developed. This design development will have a profound effect on production. Basic decisions pertaining lo the location of framing must be made along with the establishment of the material to be used in certain arcas of the vessel. Consideration should be given at this time to the standardization of frame spacing, types of structural members to be utilized and the use of a minimum number of different shapes, all in order to simplify fabrication. Methods of structural member fabrication should be considered as well including stiffeners and supports (rolled vs. built-up vs. flanged plate), bulkheads (plate-sliffeners vs. corrugated), etc.

In this phase, the designer has considerable freedom to attempt innovative structural arrangements. As a minimum, he should avoid the USC of fabricated shapes which inherently have greater work content than standard rolled shapes. If it is shipyard practice to utilize fabricated shapes. then this should be re-analyzed.

If weight is a serious consideration, then an innovative approach based on more detailed structural analysis may provide a more optimum solution. Alternatively. a review of the main design parameters can be undertaken with an eye towards relaxation of those having the greatest negative impact. Both of these alternatives should be investigated rather than rigid applications of rules and guidelines to a weight-sensitive design, which may result in a design incorporating complex fabrication and a wide variety of material sizes. On the other hand, as it is to be expected that material costs will be less than labor, where weight is not a serious problem a reduction in stiffening with increased plate scantlings should seriously be considered as a means of reducing the number of welded components and thereby reducing labor.

Contract Design

The contract design phase utilizes the outputs established during the conceptual/preliminary design phase, refines the functional requirements established in the owner's specification. and establishes the basic key information necessary for all subsequent design phases. Furthermore, it establishes the features of a design in sufficient detail to provide the basis of a contractual arrangement.

If the design is prepared by a shipyard, it should be easier to facilitate the introduction of producibility. If an organization external to the shipyard develops the design, e.g. a design agent, it is still possible to introduce producibility through the incorporation of those attributes which should be conducive toe increasing producibility at any shipyard.

This phase can also be defined in terms of a series of inputs and outputs with the major input data emanating from a conceptual/ preliminary design. The principal information will consist of the following:

Design Inputs

- Conceptual/Preliminary design,
- Functional requirements,
- Regulations. and
- Design standards,

Design Outputs

- Building specification.
- General arrangement,
- Midship section.
- Hull lines plan,
- Design calculations,
- Accommodation arrangements.
- Machinery arrangements,
- Piping Diagrams,

- Electrical load analysis, and
- Plan list;

Production Inputs
- Shipbuilding policy,
- Company standards and industry standards including: material sizes, fabrication preferences, module make-up, service runs, block sizes,

spatial analysis:

Production Outputs
- Preliminary build strategy: planning units,
- Equipment identification: long lead ilcms.
- Material requirements: quantities, long Icad. and
- Preliminary list of units and modules.

General Arrangements. As the design continues to evolve and as engineering calculations arc completed, an increasing amount of information concerning equipment becomes available`. This information is incorporated into the contract specification and allows for the furthor detailing of the machinery arrangement drawings, the accommodation and the hull general arrangements.

In developing the arrangements, there is considerable scope for influence on producibility. The designer has an opportunity to reduce ship cost by use of spatial analysis which considers the ship as a set of functional spaces rather than a set of systems. These functional spaces are specific volumes within the ship which contain functionally interrelated equipment and are initially defined in terms of their circumscribing envelope. Detailed internal design and precise locations of equipment within these spaces arc left to a later design phase provided only that it is certain that sufficient space is available. However, very effective strategy can be developed at this point to group equipment and outfit for modularization, standardization and interconnection to system interfaces at the boundary of the functional space.

Service routes can be treated in the same manner. The designer should allocate volume to a series of main and secondary routes. In addition, the priority of the distributive systems should be examined and rearrangement of compartments made where possible to simplify routes, reduce run lengths and simplify installation.

At the same time producibility enhancements are introduced the contract arrangements must exhibit a well thought out access to all spaces within the ship. This will not only be important to the owner whch operating the ship but during the construction process as well.

Hull **Form.** The hull form is established during the preliminary design phase, however, the development of the design may result in some revisions being required. These should be minor, to take account of small variations in weight distribution, wake field as measured in model tests or final fairing.

Structure. The midship section should be completed in terms of structural components and arrangements. Scantling plans depicting the remainder of the vessel's structural arrangement are required as well. Both of these should be produced in a formal to suit classification or other approval bodies, and although preferable, may not yet be fully developed to approval standard. In the case of novel or unusual features, discussions should be held with classification societies and regulatory bodies.

Production input to this stage of structural design is of major value, importance and potential impact. The location and spacing of the principal structural members should be finalized from a production point of view to best suit the production process. The designer should also be guided by production in the selection of the material sizes and fabrication processes used.

Welding techniques, character and inspection should be identified. Potential situations for special welding, such as in thick weldments utilized where castings might normally be incorporated, should be carefully planned.

Machinery Arrangements. At the start of the Contract Design, the machinery arrangement may actually consist of only the outline of the prime mover and shafting system shown on the preliminary general arrangement drawing. In this phase, separate drawings should be prepared.

As the design develops, an increasing amount of information will become available describing the machinery and equipment to be located in the machinery spaces. From a production point of view, the arrangement should facilitate the unit and modular construction approach. In particular, the arrangement of similar equipment in common locations, along with a strategy for producing modules with support structure and piping will signilicantly reduce the planning and potential re-design which might otherwise be required during the Transition Design.

Ship Systems. Calculations pertaining to various piping, electrical and heating, ventilation, and air conditioning (HVAC) systems will be developed and specifications written for each. This information will guide the designer in the development of piping and HVAC diagrams, the one line electrical drawing, and will provide the baseline for future activities. It is important to note that vendor information will be required in order lo develop some of the more complex system diagrams.

Development of the system diagramatics and one line electrical drawing is carried out in stages. A flow diagram or schematic showing the connections between the main and auxiliary equipment is drawn for each system. This flow diagram does not yet show capacity or piping and duct diameters but identifies the functionality of the system. The capacity of each of the major components is then determined and provides the basis for the technical specification. This will identify all the necessary information; for example, voltage, capacity, and pressure. together with any other relevant information which influences the choice of the component.

The flow diagrams arc then completed to give. a preliminary insight as to the pipe diameters, pump capacities, pressure and valve types for all connected equipment. This allows the specification of all items not previously identified to be developed. The flow diagrams are limited in USC from a production point of view as they do not reflect the actual position of systems within the vessel. However, they provide a comprehensive description of all material and equipment making up the system. This affords the opportunity to assure that standardization of components and equipment has been achicved to support availability and stockpiling considerations at a shipyard.

Drawing List. Once all the systems within a vessel have been identified and the structural arrangement has been established. a preliminary drawing list should be prepared. In parallel with the design development a preliminary build strategy should have been developed. This will identify the planning units, structural units, outfit asscmblics. equipment modules and zones based on the functional spaces which make up the vessel. Utilizing this data two sets of drawings can now be listed.

Conventional drawings will include all approval drawings, and those which define the ship from a functional and systems standpoint. In addition, a set of production drawings related lo each planning unit will give all the neccessary production information for manufacture, assembly and installation.

The drawing list should form part of the contractual arrangements. In a more evolved form, it will identify the responsibility and schedule for each piece of information needed in the remaining design process. When a design subcontractor is utilized by the shipyard this bccomos especially important for establishing the extent of the effort requircd. When shipowner furnished material or information is in a critical path. the identification of this input will insure a more orderly arrangement.

PHILOSOPHY OF THE DESIGN PACKAGE

The manner in which a design package is prepared and utilized will generally be dependent on the source responsible for its development:

- Commercial Shipowner,
- Government (Navy, Coast Guard, etc.), or
- Shipyard.

Each of these sources is concerned with the utilization of the design package by different organizations or disciplines although the final desired outcome should be identical: a quality vessel meeting the required needs for a favorable price. Furthermore, the manner in which the outputs of different design phases are utilized.differs as well for each of these sources.

Commercial Shipowners

Commercial shipowners are principally concerned with obtaining a vessel meeting their performance requirements at a favorable price. They are not always interested in developing a custom design and although their staff may be comprised of individuals knowledgeable in design, this is generally not their primary function within the organization. Most likely, there are even fewer personnel on the staff knowledgeable in ship production.

As a result, the shipowner is usually most interested in obtaining shipyard proposals for vessels of their own particular design meeting the owners performance requirements. Following a request, many expect a formal quotation supported with specifications and selected drawings to be submitted to them in short order.

Shipowners may tend to be unconcerned with the distinction between the design phases as long as they arc comfortable that the risk in the price quotation based on a particular design and its stage of development is within the margin they can accept at contract signing. They will seek to understand the character of not only the principal design characteristics but the intended details of the construction and character of the equipment which are to be provided. As it may be unlikely this will all be known from the current design phase development, a comparison to previous designs may be acceptable. In the final analysis, the owner will be less concerned with the design process between the original quote and the detail design for construction than the shipbuilder.

The shipowner's in-depth review of the design will be through the Contractual Plan Approval process consisting of a review of detail design drawings and reports reflecting all aspects of the design. Generally, detail design drawings for review will be a conventional set of drawings, not unit or module production drawings.

Government

The U.S. Government's public shipyards are primarily devoted to modification, maintenance and repair rather than newbuilding. As a result, during new vessel acquisition, the Government may essentially be considered a shipowner. However, the comparison with the commercial owner is only similar at the point of contract signing and thereafter. Beforehand, the Government may behave much more like a shipbuilder in the manner in which the design development is carried out.

A number of Government agencies and departments maintain significant staffs of individuals knowledgeable in craft and ship design. These include the Navy, Coast Guard, National Oceanic and Atmospheric Administration (NOAA), Maritime Administration (MARAD), National Science Foundation (NSF), and others. The Government is generally much more involved in the design of a vessel from the outset, and in most cases of large and costly vessels, has developed the design significantly prior to releasing it to the shipyards for further development and/or bidding for detail design and construction. More recently, attention has also turned to ship production.

The manner in which the Government releases a design to the public may take on several forms:

- Design competition to "Performance Specifications";
- Design competition based on a "Circular of Requirements (COR)";
- "Contract Design" for Detail Design and construction bidding.

Performance specifications presumably reflect the functional characteristics desired by the operators and have probably been supported by feasibility (pre-concept) and conceptual level design studies carried out by the Government. The COR contains a more comprehensive definition of ship technical characteristics and definitions of systems than contained in performance specifications. It is usually based on Conceptual to Preliminary Design type of studies carried out by the Government.

The Government is concerned with avoiding any vessel design attribute that will favor a potential bidder. Accordingly, the characteristics relating to production that may be incorporated into a Government design effort can only be of a general nature or lhose which have been identified as facilitating production under many circumstances.

Shipyards

Shipyards may be simultaneously or separately involved with vessel design and construction programs for both commercial and governmental clients. Accordingly, it is to be cxpected that they may encounter any of the circumstances previously discussed.

Theoretically, a shipyard is free to incorporate the production attributes of the organization into the design process ill any Stage. As personnel most experienced in production may not always be associated with the design departments, successful integration of production into design must involve a coordination of disciplines.

PRODUCTION DIRECTORATE

Having knowledge of the production input and output for various designs phases and the responsibility of the organization in the design sequence, the only remaining ingredient to institute earlier design for production is the provision of a means to effect the integration of the two. The absence of a defined responsibility for introducing the production requirements into the design sequence may result in a haphazard addressing of the subject driven by the interest and knowledge of other participants in the project.

Shipowner

Shipowners are not normally sufficiently involved in the design cycle leading to Contract Design that their involvement will require considerations of shipyard production. However, their interface with the shipyard on alternative approaches that will aid production while not undermining vessel performance, operation and maintenance will be very helpful.

Alternatively, the shipyard which can anticipate a shipowner's needs and propose a vessel optimizing the production aspects will have achieved the desired balance.

Government

The Government's involvement in the design process places it in a higher visibility position with regard to affecting the producibility of a vessel. This is particularly true in those cases where a comprehensive COR or Contract Design is developed.

Any design can be built more effectively by the use of modular construction techniques than by conventional techniques, regardless of the content of the design. Thus, the lack of consideration for producibility in the early stages of design does not preclude a shipyard from using modular construction techniques. However, a Contract Design package that has not taken modular construction practice into account will result in much more potential re-design during the detail design than would otherwise be necessary. This will result in

greater engineering costs and a longer design schedule before construction can be started effectively. Riggins and Wilkins (4) have addressed this point in discussing early phase Navy ship design for producibility: "In some contracts, particularly those which are tightly time-constrained, the effort to change the design will be considered impractical, and this will be true whether the contract is cost plus or fixed priced. Thus, the potential cost savings to the shipyard and/or to the government will be lost. Why should the shipyard or the government have to pay extra engineering costs, with resultant delays, to obtain the benefits of reduced production costs, when those arrangements or other detailed requirements in the specifications could have been made before the contract package was issued?"

By considering the basic elements of design for production government agencies can eliminate a great portion of the re-design effort that may otherwise have to take place during the detail design effort. Since a ship designed for modern production can still be built any other way. no shipyard should be penalized by the incorporation of greater producibility into the design.

In order to systematically and effectively introduce production considerations, the Government can provide the interface of a production oriented engineer to work side by side with design engineers. The Navy in I990 conducted a Producibility Workshop (4) which had as one of its recommendations the establishment of extensive training programs to educate Navy engineers in modern shipbuilding methods and in the application of producibility practices.

Hofmann et al (5) have discussed considerations for producibility recently introduced by an alternate "twin skeg" ship design for the T-AO 187 class fleet oiler. There were several proposals introduced to enhance producibility features in the structural area including:

- maximized areas of flat plate,
- maximized areas of single curvature, for remaining shell plating,
- increased frame spacing and reduced numbers of piece parts in structural assemblies,
- standardized brackets and web frames, and use of bilge brackets in lieu of longitudinal stringers in the bilge turn area, and
- carefully arranged erection joints.

The intent of this alternate was to achieve procurement cost savings with an integrated hull form, basic arrangement, and structural configuration which were aimed at improved producibility. Table I demonstrates the results. These objectives and results are not believed to adversely affect the performance of the vessel as it has equal or better projected performance and intact and damaged stability characteristics relative to that achieved with the existing T-AO '187. The authors concluded with a number of guidelines for the application of producibility in feasibility, preliminary and contract design stages of U.S. Navy "T-Ships" which address modular construction of systems as well as the structural aspects just described.

Shipyards

Shipyards are in the best position to introduce production considerations at the earliest stages of design. If a design is being carried out at the shipyard facility, this may be achieved through the interaction of a "Design Director" and "Production Director". If the design activity is being carried out by a subcontractor off-premises, then it is the responsibility of the shipyard to appraise this activity of the shipyard's production preferences and this can be accomplished through the primary points of contact.

In an effort to try and construct an example of the benefits to be gained by earlier introduction of production considerations in design, consider the case of the U.S. Navy's T-AO 187 class ships just previously discussed. Nierenberg and Caronna (6) have compared these vessels as built at Avondale Shipyards utilizing advanced shipbuilding systems to the earlier AO-I77 class fleet oilers also built there, but utilizing a more traditional design and construction approach.

Table I: Producibility Savings for Twin-Skeg T-AO

Item	T-AO 187	Twin-Skeg	Difference
Double curvature plate, %	34	10 EST	
Web frames, n	30	18	- 40%
Wing tank struts, n	60	0	- 100%
Longitudinals, n	68	56	- 18%
Frames and floors, n	140	105	- 25%
Transverse bulkheads, n	24	21	17%
Bilge longitudinals, n	8	0	- 100%
Bilge brackets, n	0	36	+ 100%

These authors note that when utilizing advanced shipbuilding systems a general yard practice is to carry out extensive study and evaluation prior to finalization of the basic hull unit breakup to assure that the best compromise of fabrication cost, unit erection and outfitting consideration is achieved. Also, large multi-system machinery/piping package units are one of the most significant improvements in ship construction methods and these have to be defined as well. These considerations were applied by the shipyard to the T-AO 187 vessels as well. However, as the vessels were already at the Contract Design level when awarded to the shipyard, it would seem plausible that had more consideration been given earlier in design to production, precious time, as well as the cost of the studies on hull unit breakup and package units, would have at least partly been saved.

Table II provides the principal characteristics of these vessels and Table III the engineering deliverable parameters reported by the authors. A decrease in the study time at the outset of construction might have also cased the peak engineering manhours as additional time up-front would have been available. Their data indicates that more engineering manhours were utilized for the T-APO 187 than for the AO-177 but that the construction costs were lower in all areas. The boundaries of these reduced costs ranged from the T-AO 187 having erected steel costing 72% of that for the AO-177 to machinery installation costs of 85% of those for the AO-177.

The additional improvements over the T-AO 187 class as reported by Hofmann et al (5) and shown in Table I would have added to these already substantial benefits.

A design and build program incorporating earlier design for production would then appear to offer savings resulting from:

1. Incorporation of enhanced production characteristics,
2. optimized spatial, structural, system. outfitting and machinery arrangements to suit unitization, and
3. time saved in developing optimum unitization.

These could have the effect of advancing the engineering schedule and reducing the peak manhour level or engineering schedule. The latter will most significantly reduce cost as it should shorten the shipbuilding program.

CONCLUSIONS

There are several conclusions to be drawn from the information presented which point to the possibilities of introducing earlier design for production and the benefits to be derived.

There arc adequate means to introduce substantial production design considerations

into earlier design phases. These considerations can include the ship construction method and sequence in addition to technical characteristics of the ship that arc conducive to the facilitation of production.

The establishment of a clear understanding of production at the earlier phases will more aptly assure that all parties arc in mutual appreciation of each other's circumstances and that the intended production approach has been accurately introduced into the vessel price. It may be even more important for U.S. shipyards than foreign shipyards to have earlier design phase production integration as design staffs may be external lo their organizations.

RECOMMENDATIONS

The introduction of earlier design for production requires a structured approach to assure that the results are complete and balanced. As an example of an approach, if input and output described for the design phases earlier in this paper are utilized as a check-off list during design as each subject is addressed, then at least the breadth of the matter should have been broached. A structured means of introducing production considerations into early design phases should become an integral part of a design approach.

If personnel involved in a design effort arc not familiar with production considerations, then a production director should be identified who is familiar with such requirements and will interface with the design director to introduce the production considerations in a timely manner.

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Table II: Principal characteristics - U.S. Navy Fleet Oilers

	AO-177 Class	T-AO 187 Class
Length overall	180.29m (59 l-6 ft-in)	206.50 m (677-6 ft-in)
Length BP	167.64m (550-0 ft-in)	198.12 m (650-0 ft-in)
Beam	26.82m (88-0 ft-in)	29.72 m (97-6 ft-in)
Depth	l4.63m (48-O ft-in)	15.24 m (50-0 ft-in)
Design draft	9.75m (32-O ft-in)	10.52 m (34-6 ft-in)
Scantling draft	10.67m (35-O ft-in)	11.53 m (37-10 ft-in)
Block coefficient	0.61	0.64
Midship coefficient	0.977	0.981
Length of parallel midbody	none	none
Cargo capacity	120 000bbl	180 000bbl
Ballast capacity	8 656m^3(305 695ft^3)	11 754m^3(415 077ft^3)
Fuel oil capacity	1 91 1 m^3(67 500ft3)	2 022m^3 (71 400ft^3)
Fresh water capacity	69M^3 (2 448ft^3)	118m^3 (4 176ft^3)
Total deadweight @ design draft	18 627MT (18 333LT)	25 974MT (25 564LT)
Lightship weight	9 198MT (9 053LT)	14 947MT (14 711LT)
Horsepower	I9 910KW (26 700bhp)	24 608KW (33 000BHP)
Electrical capacity	3@2500KW	4@250kW
No. of cargo pumps	8	8
Accommodations	200	137
Trial speed. knots	21.4	22.1
Type of propulsion machinery	single screw 4137kPa (600-psi steam)	twin screw medium speed geared diesel
Propeller	Fixed pitch	CRP

Table III: Engineering Deliverable Parameters - U.S. Navy Fleet Oilers

	AO- I77 Class	T-AO 187 Class
No. of engineering drawings	1417	1844
Time period-contract to engineering essentially complete	30 months	24 months
Engineering percentage complete at keel laying	40%	65%
Relative man-hour cost per drawing	1.0	0.90
Peak engineering spending man-hours/month	23000	44000

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